"Local" NIRS PLS model vs multi species model for basic density of Eucalyptus solid wood and influence on spectral data by moisture content variability

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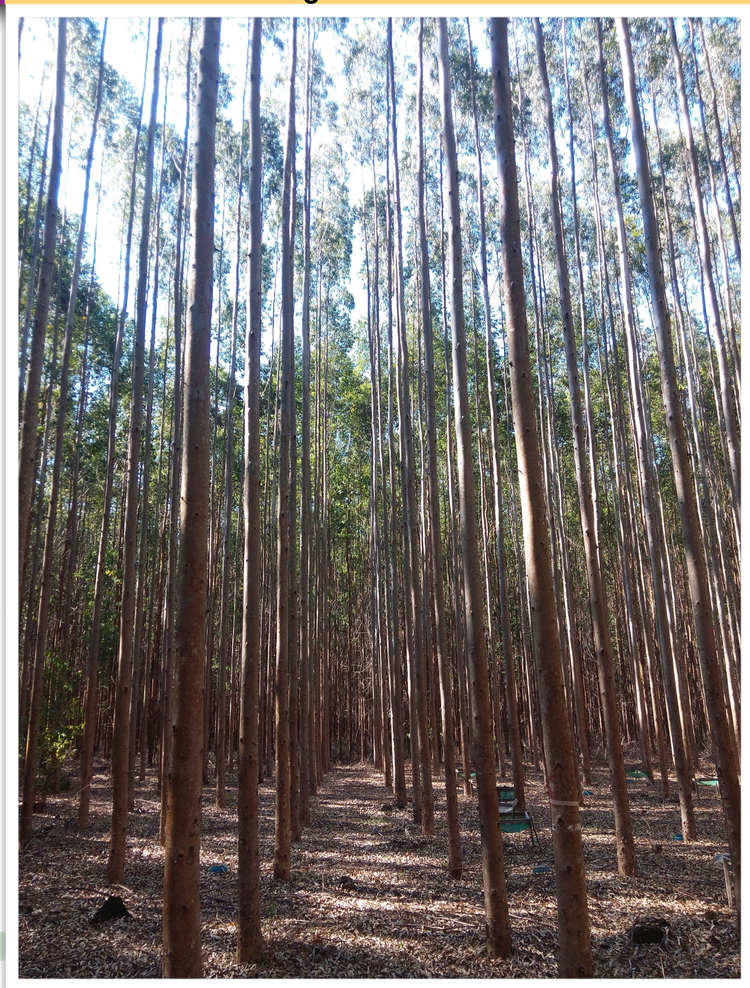
Wood basic density (BD) is mainly controlled by the ratio of fibre and the cell-wall thickness which is related to pulp yield and most physical and mechanical properties influencing wood end-using. Accordingly, BD is an important criterion for selection in tree breeding program which requires screening of large number of trees. Associated to non-destructive sampling as cores, NIRS can be used to estimate the BD.

In this objective, we built global NIRS models for basic density by using Eucalyptus multispecies datasets, issued of Brazilian wood samples representing different end-using purposes (pulp and paper, timber, charcoal, pole). We controlled moisture content (MC) variability during the NIRS measurement to incorporate this parameter to build plastic NIRS models.



Experience

- We collected wood disks on 8 to 25 year-old *Corymbia maculata, E. grandis, E. resinifera*, and *E. cloeziana* trees (10 per species). Diametric bands cut from the disks were divided in 15 x 20 x 20 mm samples. They were theoretically stabilized at 8, 10, 12, 14, 16, and 18% of MC. At each MC, we measured spectra on the same sanded longitudinal face. Spectra were measured under diffuse reflection using integration sphere of a Bruker MPA spectrometer, each spectrum constituted of 16 scans. Spectral analysis was performed within the 9,000–3,500 cm^{-1} range at 8 cm^{-1} resolution. BD, the mass of oven-dry wood per unit of volume of green wood, is expressed in grams per cubic centimeter. Corrected MC was calculated by taking into account the dry weight data.

- We used Unscrambler software 10.3 (Camo, Norway) for PLS regression of BD at different MC, for all species or separately. Cross-validations with 5 groups of random samples and validation test sets were performed to compare models.

Results and discussion

- The BD range was comprised between 0.390 and 0.898 g/cm^3. The corrected MC varied from 9 to 22 %, showing bias with the theoretical MC, according to the species. Global models including the 4 species and MC variability, showed RMSEP = 0.040 g/cm^3 and RPD = 3.9 (Table I). As expected, models developed with spectra of theoretical MC were less efficient than the model developed with spectra selected at corrected MC. For example at 12% for MC, values of RMSEP and RPD for multispecies model were respectively 0.040 g/cm^3 and 3.8 for theoretical MC, and 0.032 and 5.4 for corrected MC (Table I, Figure 1).

Table I: Results of cross validation and test set validation for basic density NIR model according to species and moisture content (CV: cross-validation, Test set: Test set validation, RPD_{CV}: RPD in cross validation, MC: Moisture content, 4 species including *E. grandis*, *E. resinifera*, *E. cloeziana* and *C. maculata*, 3 species: the same excepted *E. grandis*).

Species	MC	Validation	N	SD	min	max	RMSECV	R^2	RMSEP	r^2	RPD
4 species	All MC	CV	692	0.157	0.390	0.888	0.041	0.93	-	-	-
		Test set	460	0.154	0.390	0.888	-	-	0.040	0.93	3.9
	MC 12 cal	CV	118	0.177	0.390	0.885	0.035	0.96	-	-	-
		Test set	78	0.173	0.392	0.863	-	-	0.032	0.96	5.4
	MC 12 th	CV	116	0.158	0.390	0.898	0.040	0.93	-	-	-
		Test set	76	0.153	0.391	0.885	-	-	0.040	0.93	3.8
E. grandis	All MC	CV	220	0.058	0.390	0.621	0.013	0.98	-	-	-
		Test set	140	0.054	0.390	0.621	-	-	0.013	0.96	4.1
	MC 12 cal	CV	101	0.050	0.390	0.602	0.015	0.89	-	-	3.3
3 species	All MC	CV	492	0.052	0.663	0.898	0.015	0.90	-	-	-
		Test set	300	0.054	0.663	0.898	-	-	0.015	0.91	3.6
	MC 12 cal	CV	250	0.050	0.663	0.888	0.015	0.91	-	-	-
		Test set	100	0.049	0.663	0.885	-	-	0.015	0.90	3.3

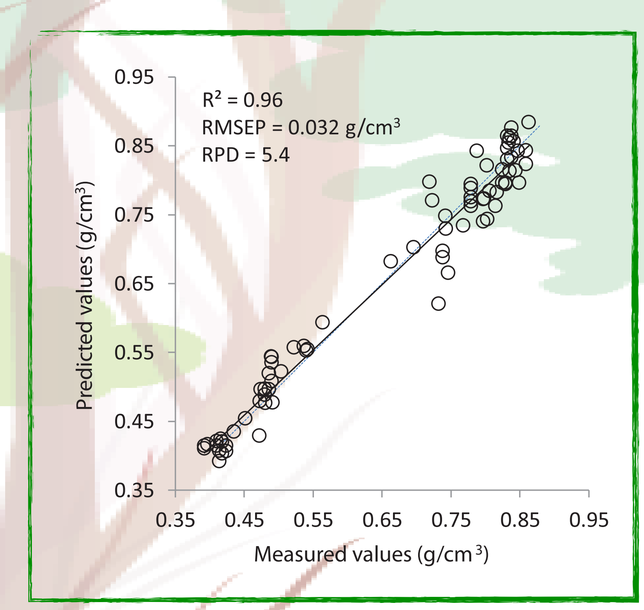


Figure 1: Multispecies basic density NIR model results (*E. grandis, E. resinifera, E. cloeziana* and *C. maculata)* - Comparison of measured values and predicted values (test set validation) by NIR for sample wood sample stabilized at +/-12% of moisture content.

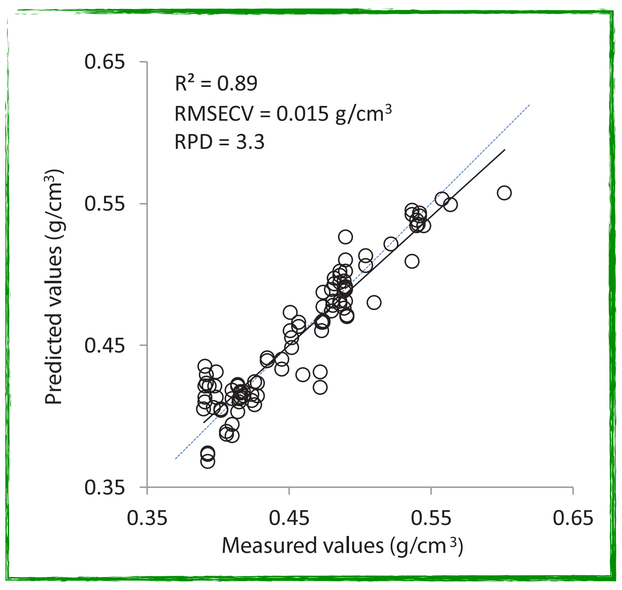


Figure 2: *E. grandis* basic density NIR model results - Comparison of measured values and predicted values (test set validation) by NIR for sample wood sample stabilized at +/-12% of moisture content.

- For the BD model of E. grandis, considered separately because of the lowest BD compared to the other species, we obtained RMSEP and RPD of 0.013 g/cm^3 and 4.1 including all MC (Table I, Figure 2). The values obtained with the other three species were 0.015 g/cm^3 and 3.6 (Table I, Figure 3, 4). The "local" models were generally more reliable than the global model in term of RMSEP, even if the last showed a higher RPD. It is the same principle and results than for the local model procedure for which the regression is based on the most similar spectral neighbors. Thanks of these models we are able to use NIR for BD prediction in different moisture content conditions.

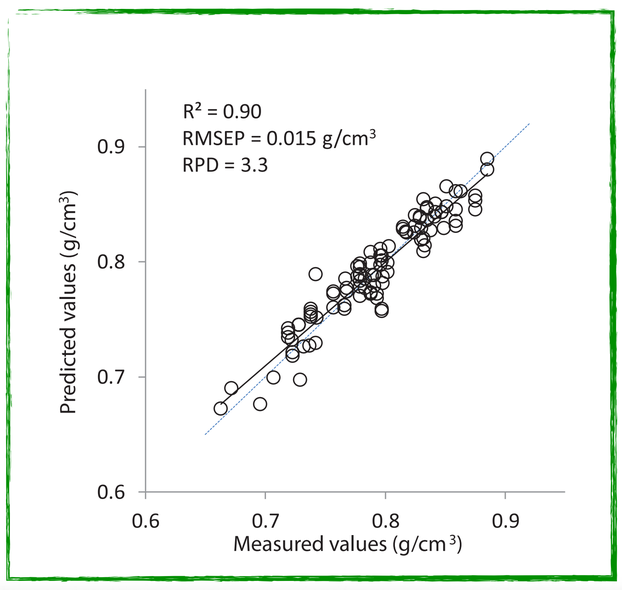


Figure 3: Multispecies basic density NIR model results (*E. resinifera, E. cloeziana* and *C. maculata)* - Comparison of measured values and predicted values (test set validation) by NIR for sample wood sample stabilized at +/-12% of moisture content.

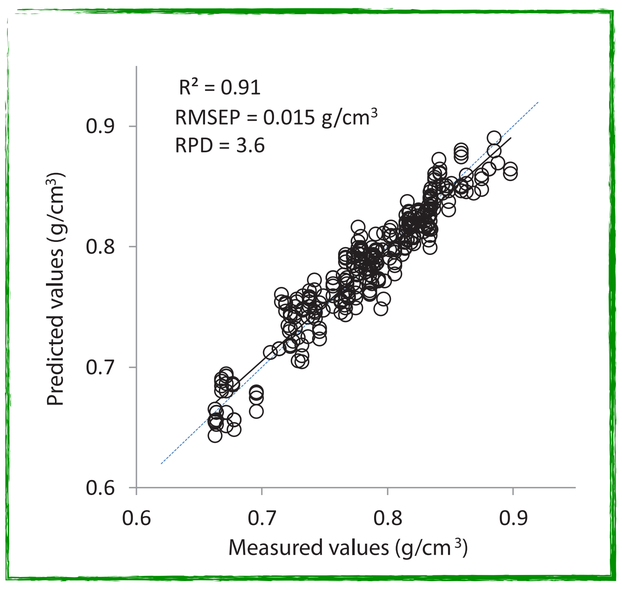


Figure 4: Multispecies basic density NIR model results (*E. resinifera, E. cloeziana* and *C. maculata*) - Comparison of measured values and predicted values (test set validation) by NIR for sample wood sample stabilized from 9 to 22% of moisture content.

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